WHAT IS CLAIMED IS:

1. An apparatus for generating a quantum state of a two-qubit system including two qubits, each qubit being represented by a particle which invariably travels through one of two paths, the apparatus comprising:

an input unit for receiving two particles having no correlation with each other; and

a quantum gate composed of an interferometer for implementing an interaction-free measurement, the quantum gate generating a Bell state with asymptotic probability 1.

2. An apparatus according to Claim 1, wherein the interferometer includes a cavity and beam splitters sectioning the cavity into two chambers,

wherein the input unit inputs the two particles into different chambers of the cavity, the two particles consisting of a first particle and a second particle and the first particle absorbing the second particle if the first particle and the second particle come near enough to each other, and

wherein the second particle successively hits the beam splitters so that the transmitted wave component in the wave function of the second particle travels back and forth between the two chambers.

3. An apparatus according to Claim 2, wherein the particle transmittance of the beam splitters is set to a predetermined value or less so that the probability amplitude of the state in which the second particle is absorbed by the first particle by entering the chamber containing the first particle when the second particle hits each of the beam splitter is set small, and

wherein the first and the second particles repeatedly approach each other with an extremely small probability amplitude so that the first particle absorbs the second particle with probability close to zero,

whereby the second particle is put into different chambers depending on whether the first particle is input to the cavity.

4. An apparatus according to Claim 3, wherein the input unit inputs the first particle to one of the chambers while the first particle is in a quantum superposition of present and absent states, so that the first particle and the second particle are put into the Bell state with asymptotic probability 1.

5. An apparatus according to Claim 3, wherein the input unit causes the first particle to pass through an additional

beam splitter for implementing a Hadamard transformation and thereby inputs the first particle to one of the chambers while the first particle is in a quantum superposition of present and absent states, so that the Bell state is generated with asymptotic probability 1 if the number of times the second particle hits the beam splitters in the interferometer is large.

6. An apparatus according to Claim 3, wherein the two particles are photons and the Bell state is generated using an auxiliary system including a three-level atom by regarding a ground state in which the atom can absorb the photons as a state in which the second particle is absorbed by the first particle and a first excited state in which the atom cannot absorb the photons as a state in which the second particle is not absorbed by the first particle.

7. An apparatus according to Claim 6, wherein a transition of the atom between the ground state and the first excited state is implemented by Rabi oscillation, and the energy of the two photons is the same as the difference in energy level between the ground state and a second excited state of the atom.

8. An apparatus according to Claim 3, wherein the two

particles are a positron and an electron and the Bell state is generated by regarding a state in which a photon is generated by pair annihilation of the positron and the electron as the state in which the second particle is absorbed by the first particle, the pair annihilation occurring if the positron and the electron come near enough to each other.

9. An apparatus according to Claim 3, wherein the two particles are a hole in a semiconductor and a conducting electron and the Bell state is generated by regarding a state in which a photon is generated by pair annihilation of the hole and the conducting electron as the state in which the second particle is absorbed by the first particle, the pair annihilation occurring if the hole and the conducting electron come near enough to each other.

10. A Bell measurement apparatus for a two-qubit system including two qubits, each qubit being represented by a particle which invariably travels through one of two paths, the Bell measurement apparatus comprising:

an input unit for receiving the state of the two-qubit system;

at least one quantum gate composed of an interferometer for implementing an interaction-free measurement;

an observation unit for observing the quantum gate after the quantum gate has processed the state of the two-qubit system; and

an identifying unit which performs a Bell measurement for selecting the state of the two-qubit system from among the Bell bases on the basis of the result of the observation.

11. A Bell measurement apparatus according to Claim 10, wherein the Bell measurement apparatus comprises one quantum gate and the identifying unit performs the Bell measurement with maximum probability 3/4.

12. A Bell measurement apparatus according to Claim 10, wherein the Bell measurement apparatus comprises four quantum gates and further comprises a beam splitter for implementing a Hadamard transformation, the four quantum gates and the beam splitter processing the state received by the input unit, and the identifying unit performs the Bell measurement with maximum probability 1.

13. A quantum gate apparatus for implementing a controlled-NOT gate transformation of a two-qubit state, the quantum gate apparatus comprising:

a Bell measurement apparatus according to Claim 10; and

a quantum circuit composed of a beam splitter for

implementing a Hadamard transformation and a quantum gate composed of an interferometer for implementing an interaction-free measurement,

wherein the controlled-NOT gate transformation of the two-qubit state is implemented by generating a four-qubit state $|\chi\rangle=(1/2)[(|00\rangle+|11\rangle)|00\rangle+(|01\rangle+|10\rangle)|11\rangle]$ using the quantum circuit gate, performing the Bell measurement for the two-qubit state and the four-qubit state twice using the Bell measurement apparatus, and applying a Pauli operator to qubits which have not been processed by the Bell measurement apparatuses depending on the result of the Bell measurement.

14. A quantum gate apparatus according to Claim 13, wherein the Bell measurement apparatus is the Bell measurement apparatus according to Claim 11 and the controlled-NOT gate transformation of the two-qubit state is implemented with maximum probability 9/16.

15. A quantum gate apparatus according to Claim 13, wherein the Bell measurement apparatus is the Bell measurement apparatus according to Claim 12 and the controlled-NOT gate transformation of the two-qubit state is implemented with maximum probability 1.

16. A method for evaluating the fidelity of a quantum

gate composed of an interferometer for implementing an interaction-free measurement, the method comprising the steps of:

determining an absorption probability with which a first particle absorbs a second particle in the interferometer; and

calculating, if the absorption probability is less than 1, an approximate fidelity of the quantum gate under the condition that the number of times the second particle hits beam splitters in the interferometer is sufficiently large.